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## COMFORT EVALUATION OF THE C-118 PILOT SEAT (AEROTHERM)

One of a Series of Studies Pertaining to the Design  
Evaluation of Pilot and Crew Station Equipment

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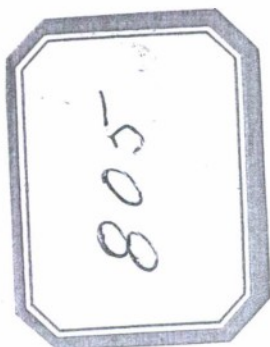
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TUFTS UNIVERSITY

MARCH 1959

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AERO MEDICAL LABORATORY  
WRIGHT AIR DEVELOPMENT CENTER  
AIR RESEARCH AND DEVELOPMENT COMMAND  
UNITED STATES AIR FORCE  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO



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CONTRACT No. AF 33(616)-3068  
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## FOREWORD

The study described in this report was carried out by the interdisciplinary staff of the Bio-Mechanics Laboratory, Tufts University, Medford 55, Massachusetts. It is one of a series of reports presenting results of the evaluation of several types of transport aircraft pilot and crew seats obtained in a comfort evaluation program (Task No. 71724) being conducted as part of the work under Contract AF 33(616)-3068, Project No. 7215, "Human Factors in Design Research."

Mr. Charles A. Dempsey, Biophysics Branch, Aero Medical Laboratory, was the Project Engineer, and Mr. W. K. Carter was the contractor's Project Director. Credit for over-all planning and general orientation of the program should go to Mr. Dempsey and several other staff members of the Aero Medical Laboratory.

Procedures for the specific testing program reported herein were planned, and the data analyzed by Dr. R. F. Slechta. Mr. Jess Forrest was responsible for interpretations concerned with seat design. Staff support and advice on testing procedures and interpretations were supplied by other members of the research group. Represented in the interdisciplinary research team were: physiology, psychology, anthropology, and industrial design.

The authors wish to thank Mr. Charles LaMuniere and Mr. H. Wade Seaford for technical assistance. We also are grateful for critical appraisals and advice on procedures to Dr. Edward M. Bennett.

In addition, we feel indebted to the subjects. Their cooperation and earnest attitudes were of primary importance to the project. Many of the subjects were members of the Tufts University AFROTC. Col. Herman Hauck, USAF, Commanding Officer of the unit, and members of his staff, aided in interesting subjects in participating and were helpful to the program on many other occasions.

We should also like to thank Frances E. Leighton, LeRoy Christie, Richard P. Karam, and Robert A. Hayes for aid in preparing the report.

## ABSTRACT

This study was undertaken in order to evaluate certain design characteristics of the C-118 Pilot Seat (Aerotherm) in terms of their adequacy for the maintenance of human comfort.

The method of evaluation consisted primarily of subjective and behavioral laboratory tests administered by means of hourly questionnaires presented to seventeen subjects during a voluntary sitting period of seven hours maximum duration.

While the permitted maximum duration of sitting time was 7 hours (420 minutes) the average voluntary time spent in the seat was 403.5 minutes. On a comfort scale ranging from intolerable discomfort (-10) to ideal comfort (+10), the average of the ratings assigned was +6.59. Hourly scale evaluations of the comfort of the seat revealed that constant moderate to extreme comfort was provided for the first five hours. Hourly evaluation of discomfort in specific body regions indicated that for all body regions the average time of onset of discomfort was 220 minutes, and that the most discomfort was experienced in the buttocks and back. Evaluation of the individual seat parts revealed certain inadequacies in the manipulative aspects of the adjustment controls.

On the basis of test data and specific comments made by the subjects, recommendations for seat design improvement were made.

## PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

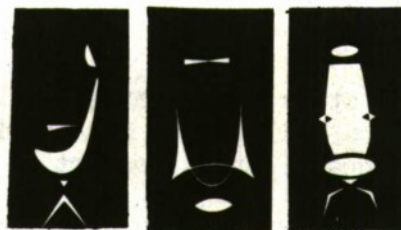


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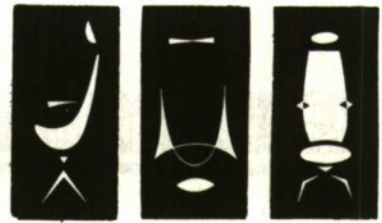
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## COMFORT EVALUATION OF THE C-118 PILOT SEAT (AEROTHERM)

### PURPOSE

This report presents the results of laboratory studies which have been applied to the C-118 Pilot Seat (Aerotherm) to evaluate the suitability of its design features in terms of human comfort. This report is one of a series presenting individual results from a group of five aircraft seats which were considered comparatively in WADC TR 57-136 (1). The present report evaluates seat parts and presents subjects' reactions to this particular seat in more detail than did the comparative study.

### DESCRIPTION OF THE SEAT

The C-118 Pilot Seat (Aerotherm) is adjustable in height, fore and aft directions, and back angle. It has armrests, but no headrest or thigh pads. The cushions are upholstered in leather and the fillers are of foam rubber. Figure 1 and the accompanying legend present further information about the construction of the seat.

### TESTING PROCEDURE

The tests were carried out using seventeen male subjects selected from the Tufts University student population. They ranged in stature from 64.2 to 74.6 inches and in weight from 125 to 205 pounds.

During the testing sessions, the subjects wore anti-g suits loosened for comfort. Protective headgear was not worn. Each subject was required to sit in the seat until his discomfort reached such a point that he felt compelled to get out of it. During this time, he was allowed to study, but was not allowed to write. If a subject did not voluntarily leave the seat, the test was terminated by the monitor after 420 minutes (7 hours).

During the sitting period, identical Test Questionnaires were presented hourly to follow changes in the subject's state of comfort and opinion of the seat. After termination of the sitting period, a final Post-Test Questionnaire was administered which asked the subject to rate the seat on a "comfort scale" and to comment as he wished on specific design features.

For a more detailed description of the questionnaire and testing procedures used, the reader is referred to WADC Technical Report No. 57-136 (1). This report also compares test results obtained from the C-118 Pilot Seat (Aerotherm) with those from four other transport aircraft pilot and crew seats.

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Manuscript released by the authors June 1958 for publication as a WADC Technical Report.

LEGEND  
C-118 Pilot Seat (Aerotherm)

DIMENSIONS

Seat Pan

Cushion - L x W x D  
Thigh pads - L x W x D  
Remarks

19" x 20" x  $4\frac{1}{4}$ " to  $3\frac{1}{4}$ "\*  
None  
\*Tapered, contoured in all dimensions.

Armrests

Cushion - L x W x D  
  
Inside distance between  
Height of top surface from surface of  
seat cushion  
Movable or fixed  
Remarks

Left  $13\frac{1}{2}$ " x  $4\frac{3}{4}$ " x 2"  
Right 10" x  $3\frac{3}{4}$ " x 2"  
 $17\frac{1}{2}$ "  
  
8"  
Movable with seat back  
Armrests differ in shape and dimension.

Seat Back

Cushion - L x W x D  
  
Headrest - L x W x D  
Remarks

23" x 20" x varies from 2"\* to 6"  
None  
\*Side curved; all surfaces contoured

Maximum envelope - based on full range of adjustments - L x W x H

41" x 26" x  $45\frac{1}{2}$ "

ADJUSTMENTS

Fore and aft - range from neutral; increment  
Vertical - neutral SRP; (range); increment  
Seat pan angle - relative to horizontal  
Seat back angles - relative to horizontal

+  $3\frac{1}{2}$ "; 1"  
 $16\frac{1}{2}$ "; (13" - 20");  $\frac{1}{2}$ "  
9° fixed  
100° 106° 110° 115° 119°  
123° 127°  
91° 97° 101° 106° 110°  
114° 118°

Included angle

Swivel  
Lateral

None  
None

UPHOLSTERY

Covering  
Filling

Leather, red  
Foam Rubber





Figure 1.

C-118 Pilot Seat (Aerotherm)



## RESULTS

**Voluntary Sitting Time:** Under the present experimental conditions the length of voluntary sitting time serves as a measure of a subject's discomfort tolerance for the seat. Table 1 presents the data from this test.

Table 1. Voluntary Sitting Time		
No. of Hours Seat Tolerated	Subject	
	No.	Percent
1	17	100
2	17	100
3	17	100
4	17	100
5	17	100
6	16	94.1
7	10	58.8

The average length of voluntary sitting time for the group of seventeen subjects was 403.5 minutes and the range was 335 to 420 minutes. Data for each subject may be found in the Appendix, Table 4.

During the sitting period, the subject was asked hourly to predict how much longer he could remain in the seat. Those subjects who did not voluntarily leave the seat and thus sat for the full seven hours predicted, at the termination of the test, that they could have remained for 2 to 2½ hours longer. Thus 10 (58.8%) of the subjects estimated that the seat could be tolerated for from 9 to 9½ hours of continuous sitting.

**Comfort Rating:** At the end of the sitting period, the subjects were asked to rate the seat in terms of the general comfort it provided on a scale ranging from intolerable discomfort (-10) to neutral (0) to ideal (+10) comfort. The rationale for converting qualitative information into scalar form (Fig. 2) is the same as that employed in a previous study. See "Philosophy Underlying Use of Rating Procedures," p. 111, WADC TR 57-136 (1).

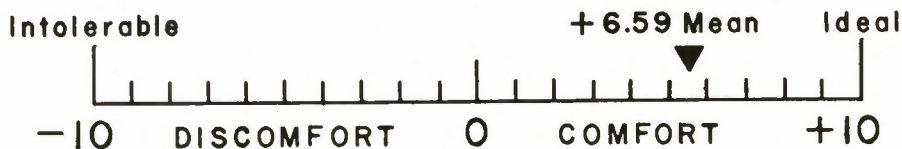


Figure 2. Comfort Rating Scale

The mean rating (+6.59) for the seventeen subjects is represented on the scale. This rating indicates in general that the seat provided better than moderate comfort. Individual ratings for the seat may be found in the Appendix, Table 5.

Hourly Evaluation of Comfort-Discomfort: Each hour subjects were asked to evaluate the seat in terms of the comfort-discomfort it was providing at the moment. They were asked to check one statement in a series of nine which ranged from a highly positive statement (+4) to a neutral statement (0) to a highly negative statement (-4). The numbers thus assigned to each checked statement were then averaged for all subjects for each hour (Fig. 3).

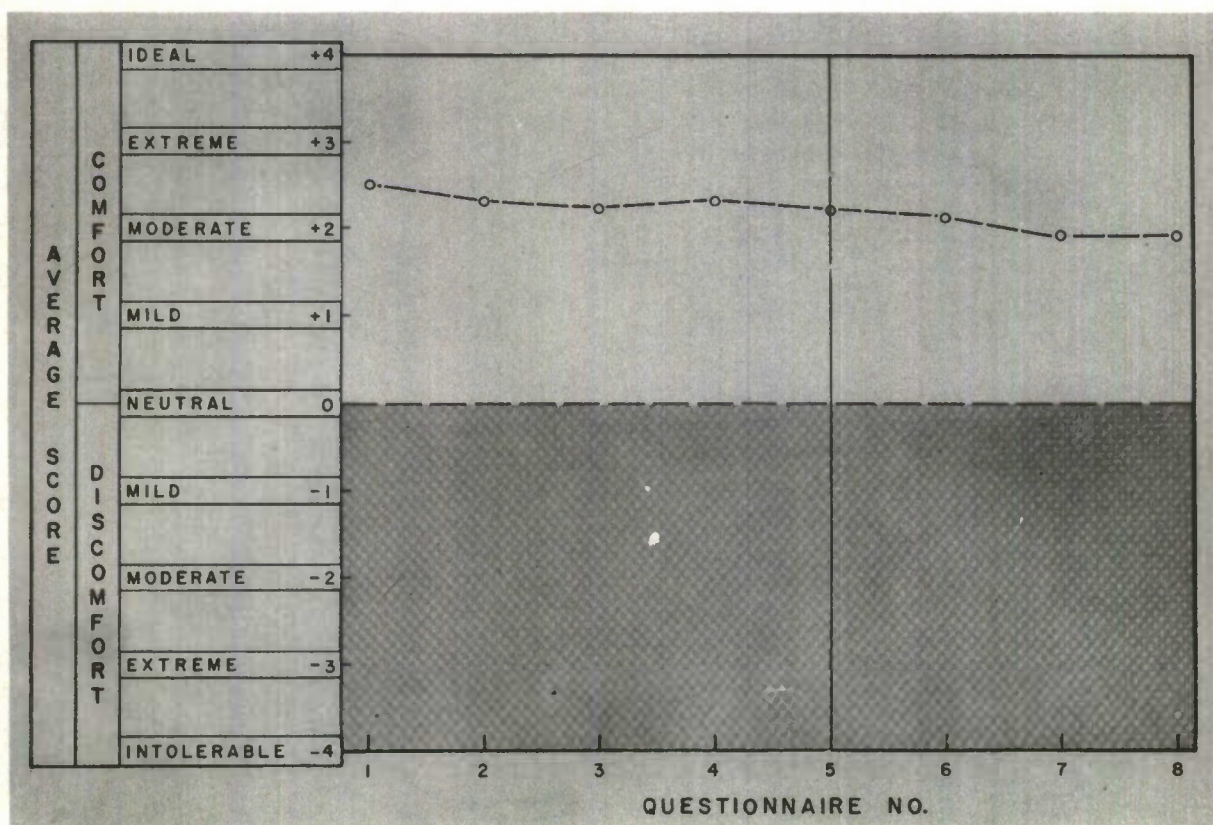


Figure 3. Hourly Evaluation of Comfort-Discomfort



Since questionnaire No. 1 was given as soon as the subject entered the seat (0 time), the fifth questionnaire corresponds to the end of the fourth hour. This data should be considered as particularly meaningful only up to the fifth questionnaire since after this time some subjects left the seat and thus fewer contributed to the average. The graph indicates that, in general, the seat provided moderate to extreme comfort for four hours. This level remained quite constant throughout the period, indicating that the seat has excellent comfort maintaining characteristics.

Body Discomfort: Subjects were also asked hourly to estimate the degree of discomfort felt at the moment in each of several body regions. The choices ranged from "none," to "slight," to "moderate," to "severe," to "very severe," to "intolerable." Rank numbers, ranging from 0 for "none" to 5 for "intolerable," were assigned to each degree of discomfort and then averaged for all subjects for each hour (Fig. 4). (See Appendix, Table 6.) Again data from only the first five questionnaires should be considered as particularly meaningful.

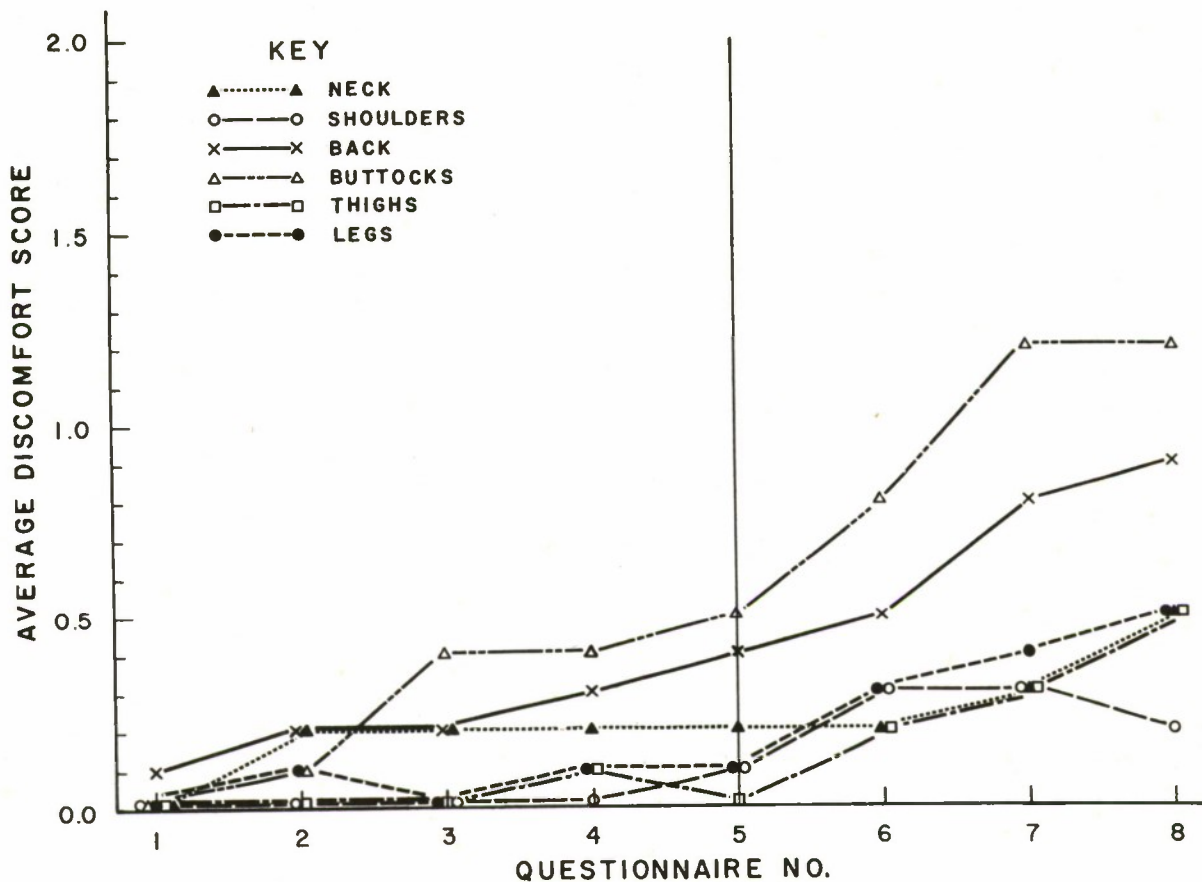


Figure 4. Average Hourly Discomfort in Each Body Region



The graph shows that although back discomfort and buttocks discomfort were of greater magnitude than discomfort in the other body regions, they were not marked. Discomfort in the neck, shoulders, thighs, and lower legs was negligible and discomfort in the buttocks and back was slight.

Hourly data were also obtained on the times that discomfort began in each of the pertinent body regions. The following table presents these data.

Table 2. Average Time of Onset of Discomfort

Body Region	No. Subjects Reporting Discomfort	Average Time of Onset of Discomfort
Neck	7	197.1
Shoulders	6	240.1
Back	10	180.0
Buttocks	12	210.0
Thighs	5	300.0
Lower Legs	5	252.0
Average for all Body Regions		220.0

The table shows that back discomfort and buttocks discomfort were felt by a majority of the subjects and were among the earliest in onset, although only after about three hours. In general, the seat remains comfortable for nearly four hours.

Evaluation of Seat Parts: In the Post-Test Questionnaire, given after termination of the test, subjects were asked to evaluate certain characteristics of each seat part and to make any further comments that they wished. The following paragraphs treat each seat part separately and list the numbers of subjects who made specific suggestions on how the seat parts could be improved to yield more comfort. Subjects' comments about each seat part are also included.

The Seat Cushion:

should be:

softer	1
firmer	1
wider	0
narrower	0
longer	0
shorter	1

should provide better cushioning for:

the base of the spine	0
the buttocks	6
the thighs	2

Subjects' Comments:

1. "The seat cushion should be about 1 in. shorter to eliminate rubbing against the under side of the knee" (popliteal area).

The Back Cushion:

should be:

softer	0
firmer	2
wider	0
narrower	0
longer	1
shorter	0

should give better support to:

the shoulders	1
the middle of the back	2
the small of the back	4

Subjects' Comments:

1. "The contouring of the back cushion allows the upper thoracic portion of the vertebral column to sink in, leaving the shoulders slightly hunched forward." (Comment made by 1 subject.)

The Armrests:

should be:

longer	3
shorter	0
wider	2
narrower	0
further apart	2
closer together	0
higher	0
lower	0

Subjects' Comments: None

Other Comments:

1. "The seat should be provided with a headrest." (Similar comment made by 9 subjects.)

2. "The leather upholstery has poor ventilating properties and causes the back and buttocks to sweat." (Similar comments made by 5 subjects.)

3. "The metal shoulder harness strap guide which is located on the top edge of the back cushion is an undesirable feature. When one brings his head back to rest, it falls on the metal strap guide." (Comment made by one subject and concurred with by the authors.) (See Figure 5 on page 10.)

#### Seat Adjustability:

Enough adjustability	14
More seat pan adjustability needed	1
More seat back adjustability needed	0
More height adjustability needed	0
Other	1 (small of back)

#### Subjects' Comments:

1. "Some sort of an adjustable pad should be provided for the small of the back." (Comment made by one subject.)

#### Seat Adjustability Controls:

Table 3. Frequency of Comments on Seat Adjustment Controls

Control	Just Right	Ade-quate	Inade-quate	Hard to Reach	Inac-cessible	Hard to Move	Con-fusing
Back Angle	9	4	2	2	0	0	0
Height	12	3	0	2	0	2	0
Fore and Aft	12	4	0	1	0	0	0

#### Subjects' Comments:

1. "The seat adjustment controls are hard to reach when the lap belt is fastened." (Similar comments made by 2 subjects.)

2. "The back angle adjustment mechanism needs a stronger spring." (Comment by one subject and concurred with by the authors.) (See Figure 6 on page 10.)

3. "The back adjustment mechanism necessitated the use of both hands." (Comment made by one subject.)



Figure 5

Shoulder Harness Guide -- Note location and interference with use of back cushion.

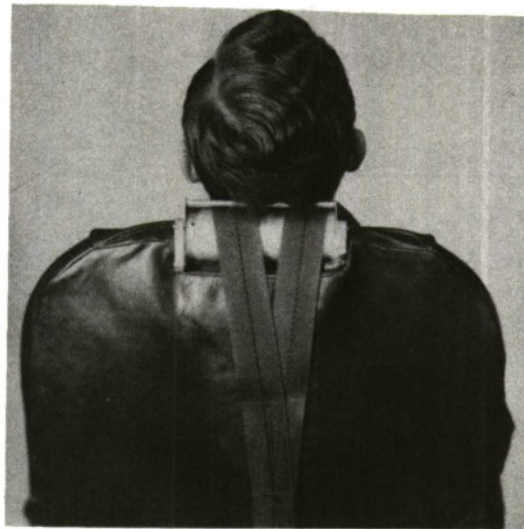
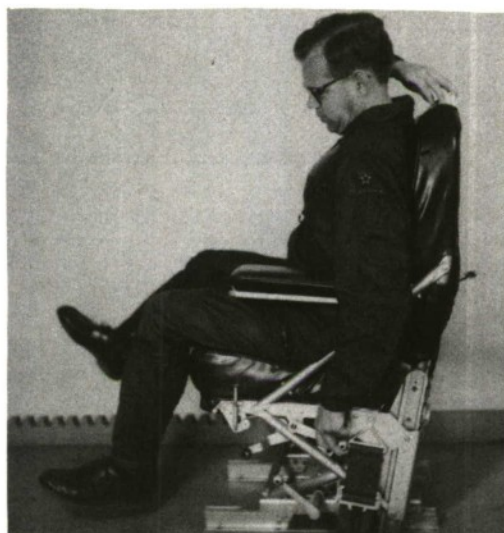


Figure 6

Back Adjustment -- Note the need to use both hands when decreasing back angle.



## CONCLUSIONS

1. The C-118 Pilot Seat (Aerotherm) is a moderately to extremely comfortable seat.

- a. Permitted a maximum sitting time of seven hours (420 minutes), seventeen subjects voluntarily sat in the seat for an average of 403.5 minutes. About fifty-nine percent of these subjects sat for the full seven hours, and at the end of this time, predicted that they could tolerate the seat for 2 to  $2\frac{1}{2}$  hours longer.
- b. When asked to rate the seat on a comfort scale ranging from intolerable discomfort (-10) to neutral (0) to ideal comfort (+10), the subjects gave the seat an average rating toward the positive end of the scale (+6.59).
- c. The subjects were asked hourly to indicate the degree of comfort-discomfort that the seat was providing at the moment. Data derived from this question show that, on the average, the seat provided moderate to extreme comfort for a period of 4 hours. This afforded comfort was maintained at a relatively constant level over the four hour period, indicating that the seat has excellent comfort retaining characteristics.
- d. During the sitting period, subjects were asked hourly to indicate the degree of discomfort felt at the moment in several pertinent body regions. Over a four-hour period, discomfort was not marked in any body region. Slight discomfort developed in the back and buttocks, but discomfort in the neck, shoulders, thighs, and lower legs was negligible.
- e. The average time of onset of discomfort for all the body regions was 220.0 minutes. Discomfort in the buttocks and back was experienced by the majority of subjects, but occurred only after about three hours. In general, the seat remained comfortable for nearly four hours.

2. The subjects indicated that certain structural modifications might further improve the comfort of the seat.

- a. The seat should be provided with a headrest.
- b. The leather upholstery has poor ventilating properties and causes excessive sweating on the back and buttocks.
- c. The metal shoulder harness strap guide is located in such a position that when the head is rested back on the cushion, it strikes the guide.



3. Some of the seat adjustment controls were difficult to operate.
  - a. The back angle adjustment mechanism does not snap readily into a locked position. (See Figure 6 on page 10.)
  - b. The back angle, fore and aft, and vertical adjustment control levers are difficult to operate and difficult to reach.

#### DESIGN RECOMMENDATIONS

Although the C-118 Pilot Seat (Aerotherm) is, in general, a moderately to extremely comfortable seat, the following recommendations for improving its comfort are made on the basis of the data obtained from the comfort tests and a careful analysis of the seat itself by the authors of this report.

1. The seat should be provided with a headrest which is adjustable in height and fore and aft directions.
2. In order to improve the ventilating properties of the upholstery material, perforated leather or other more porous materials should be considered.
3. The metal shoulder harness strap guide should be relocated so that it does not interfere when the head is back.
4. The fore and aft adjustment control lever should be relocated so that it is within easier reach when the lap belt is fastened.
5. The back angle adjustment control lever should be relocated about  $\frac{1}{2}$ " farther out from the seat frame to prevent scraping of the knuckles when the control is operated.
6. The back angle adjustment mechanism should be improved so that the seat back will snap easily into the upright position when it is being changed from a more reclined one. The present mechanism requires one to manually pull the seat back forward to get it locked into the most upright position.
7. The vertical adjustment control lever should be relocated so that, on upward travel, it does not come close to the inertia reel lock lever.

When the findings of this report indicate inadequate structure, accessories and seat dimensions, it should be remembered that these criticisms are based on laboratory tests of the seat, independent of its place in a particular aircraft. The authors realize that many of these inadequacies were compromises with aircraft workspace requirements. The recommendations for changes therefore, should be considered when aircraft workspace will allow them.



## BIBLIOGRAPHY

Slechta, R.F., Wade, E.A., Carter, W.K., and Forrest, J. Comparative Evaluation of Aircraft Seating Accommodation. Technical Report No. 57-136, WADC, Wright-Patterson Air Force Base, Ohio, April, 1957.

# APPENDIX

## SITTING TIME IN MINUTES

### TABLE 4

<u>Subject</u>	<u>Sitting Time</u>
1. J.R.	360
2. R.H.W.	360
3. W.B.	420
4. J.W.	405
5. B.H.	405
6. W.P.	335
7. R.T.	420
8. G.D.	420
9. R.S.	420
10. A.L.M.	420
11. B.G.	420
12. W.S.	420
13. A.M.	385
14. D.H.	410
15. D.S.	420
16. E.G.	420
17. R.N.	420
18. R.A.W.	*
Average	403.5
S.D.	26.9

\* Missing score

## COMFORT SCALE RATING

### TABLE 5

<u>Subject</u>	<u>Rating</u>
1. J.R.	/ 4.0
1. R.H.W.	/ 6.0
3. W.B.	/ 8.0
4. J.W.	/ 6.0
5. B.H.	/ 8.0
6. W.P.	/ 4.0
7. R.T.	/ 7.3
8. G.D.	/ 6.0
9. R.S.	/ 8.0
10. A.L.M.	/ 0.0
11. B.G.	/ 9.0
12. W.S.	/ 7.0
13. A.M.	/ 6.0
14. D.H.	/ 8.0
15. D.S.	/ 8.3
16. E.G.	/ 8.0
17. R.N.	/ 7.0
18. R.A.W.	/ 8.0
Average	/ 6.59
Median	/ 7.0

AVERAGE HOURLY DISCOMFORT IN EACH BODY REGION

TABLE 6

<u>Questionnaire Number</u>	<u>No. S's</u>	<u>Neck</u>	<u>Shoulders</u>	<u>Back</u>	<u>Buttocks</u>	<u>Thighs</u>	<u>Legs</u>
1.	17	0.0	0.0	0.1	0.0	0.0	0.0
2.	17	0.2	0.0	0.2	0.1	0.0	0.1
3.	17	0.2	0.0	0.2	0.4	0.0	0.0
4.	17	0.2	0.0	0.3	0.4	0.1	0.1
5.	17	0.2	0.1	0.4	0.5	0.0	0.1
6.	17	0.2	0.3	0.5	0.8	0.2	0.3
7.	17	0.3	0.3	0.8	1.2	0.3	0.4
8.	14	0.5	0.2	0.9	1.2	0.5	0.5
9.							
Questionnaires 1-5		0.8	0.1	1.2	1.4	0.1	0.3
Questionnaires 1-8		1.8	0.9	3.4	4.6	1.1	1.5



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